ABRASIVES

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WOLLASTONITE AS A COMPONENT FOR CERAMIC BINDERS FOR ABRASIVE TOOLS

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The results of studying wollastonite as a material for ceramic binders for abrasive tools are described. Its is established that wollastonite can be used as a flux. The possibility of controlling the properties of binders by modifying the content of wollastonite is demonstrated.

Wollastonite is currently finding increasing applications. Its structure and physicochemical properties [1 – 3] makes it suitable not only as a mineral source of calcium, but also as a filler and reinforcing material in the production of composite materials, refractories, and filling materials, as well as a component of glazes and porcelain mixtures.

The reinforcement of composites with a silicate matrix by wollastonite makes it possible to increase its strength, resistance to thermal impact, and resistance to destruction, due to the needle shape of calcium silicate crystals and due to reactions between wollastonite and the matrix components ensuring a strong adhesion between the matrix and the reinforcing material and increasing the strength parameters of the finished material [2].

The application of wollastonite in porcelain mixtures and glazes makes it possible to decrease their content of expensive glasses. At the same time, it becomes possible to accelerate firing and decrease the firing temperature of porcelain mixtures. Porcelain containing wollastonite has insignificant shrinkage and low water absorption. Apparently, in such compositions wollastonite acts as a flux. It is established [2, 4] that wollastonite decreases the quantity of the vitreous phase in ceramic materials. At the stage of molding and drying of ceramic mixtures, wollastonite acts as a filler improving the molding and drying properties and then participates in sintering in the course of firing.

The introduction of wollastonite into ceramic binders for electrocorundum abrasive tools, which, similarly to ceramic and porcelain mixtures, consist of argillaceous materials, feldspar and the frit of aluminosilicate glasses, also seemed advisable. It was expected that a stronger abrasive tool would be produced due to the reinforcing function of wollastonite crystals. However, the practical experience of binders with wollastonite die not achieve the expected increase in the strength and resistance of the abrasive tool.

In view of the necessity of expanding the available materials for abrasive tool binders, the behavior of wollastonite in typical binder mixtures was investigated. Samples of diameter 20 mm and height 10 mm were prepared and fired according to the standard firing procedure, then the spreadability of the samples was determined as the variation (percent) of the molded tablet diameter before and after firing. The spreadability of ceramic binders indirectly points to the temperature of firing of the tool and gives an idea of the properties of the binder in it. Thus, it is known that the spreadability of the binder, to perform standard thermal treatment, should be 150 – 180%; with a higher spreadability of the binder, shrinkage of the tool takes place.

The binders for abrasive tools differ in their component ratios and frit compositions. The structure of the binder bridges linking abrasive grains after firing depends on many factors: the binder composition, the grain size of the abrasive material, and the tool parameters [5, 6]. In a finished tool, the binder containing aluminoborosilicate glass forms porous heterogeneous bridges, in which crystals of mullite, quartz, and residual crystals of initial materials that have not entered into reactions are distributed. The binder bridges of compositions that ensure the fusion of all components into a homogenous glass impart greater strength to the abrasive tool accompanied by increased porosity. Such binders contain a multicomponent aluminosilicate glass [6].

Considering that kaolin and feldspars are the main components of ceramic binders, wollastonite was introduced into mixtures containing only kaolin and feldspar. It was found that adding wollastonite has virtually no effect on the spreadability parameter. Outwardly, the samples with wollastonite are more homogeneous after firing and have a dull white color. The microscopic study of the samples revealed that the

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behavior of wollastonite in firing with materials for ceramic binders is similar to its behavior in other ceramic compositions. Wollastonite in kaolin – feldspar compositions in firing partly melts while retaining the shape of its initial needle-like crystals rather strongly fixed to the other binder components.

The structural specifies of abrasive tools on a ceramic binder does not allow for taking advantage of this strengthening effect, due to the impossibility of a uniform distribution of wollastonite crystals in the binder bridges. The volume porosity of abrasive products is usually equal to 40 – 60%; the hard and strong abrasive grains are connected by the binder bridges of length 200 – 400 μm and of thickness lower by an order of magnitude than the specified value; it is virtually impossible to obtain reinforced layers in the binder. Decreasing the size of wollastonite crystals in accordance with the size of the binder bridges did not produce the desired effect.

TABLE 1

Composition	Wollastonite content (above 100%)	Spreadability, %	Strength of samples, MPa	Characteristics of samples
50% kaolin and 50% feldspar	–	–	Low	Sinter without change of sizes
	10	110	The same	Vitrified and blistered surface
	20	115	″	Vitrified surface
Binder with aluminoborosilicate glass	–	150 – 160	10.5	Opaque glass with crystal inclusions
	10	180	11.3	The same
	20	180	9.3	Glass with crystal inclusions
Binder with aluminosilicate glass	–	180	12.5	Glass
	10	205	11.7	The same
	15	220	12.8	Glass. Shrinkage of samples with abrasive in firing
	10*	180	12.8	Glass

* At the expense of glass.

The study of the effect of wollastonite on the spreadability of ceramic binder samples, which contained glass, in addition to kaolin and feldspar, demonstrated that wollastonite in such compositions can be regarded as a flux. The spreadability of the samples with wollastonite is 20 – 30% higher than that of initial compositions (Table 1). With a wollastonite content higher than 25%, residual wollastonite needles are observed in the melt or on the surface of fired samples. The binder samples die not change their volume that was set in molding.

When wollastonite is added into compositions with an aluminoborosilicate frit, the content of the vitreous phase in the binder bridges grows, and the quantity of residual crystals decreases.

The introduction of wollastonite into binder mixtures ensuring strong vitreous bridges in the binder increases the spreadability and decreases the viscosity of the binder melt. Therefore, it is possible to obtain compositions with spreadability and viscosity parameters needed for firing in accordance with the regimes accepted in the industry by decreasing the quantity of expensive frit. An important consequence of obtaining binders that form glass in abrasive tools and have high spreadability is the possibility of lowering the tool-firing temperatures by 100 – 150°C.

The testing of wollastonite-bearing binders was performed on highly porous tools made of white electrocorundum 25A with the grain size No. 12. The strength of the samples with wollastonite is sufficient for operating velocity of abrasive wheels of at least 35 m/sec. Highly porous wheels of diameter 500 mm based on wollastonite-containing binders have withstood the mechanical strength tests under the regimes corresponding to the wheel operating velocity of 50 m/sec.

The calculations of binder mixtures indicate that the introduction of wollastonite increases the content of SiO_2 by 2 – 5% and decreases the content of Al_2O_3 in the binder with aluminoborosilicate glass by 10 – 15% and in the binder with aluminosilicate glass by 2 – 3%.

A comparison of the chemical compositions of binders, the spreadability parameters, and the strength of abrasive composites suggests composition range limits for binders that can be definitely used in the production of abrasive tools from electrocorundum materials. The best results are obtained in compositions with the molar ratio $Al_2O_3 : SiO_2 = 0.2$ and the content $RO + R_2O = 0.25$. The binder compositions with an increased Al_2O_3 content, even with a simultaneous increase in B_2O_3 content, after firing form a vitreous, but porous phase with crystalline inclusions incapable of strongly fixing abrasive grains.

Thus, wollastonite can be regarded as a component for ceramic binders in abrasive tools. The composition range has been identified, in which the application of wollastonite makes it possible to decrease the content of expensive glasses and thus to lower the production cost of the finished product.

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